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Comparison of Chosen Acceleration Techniques for Evolutionary Algorithms Applied to Large Optimization Problems

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Introduction

Research motivation

A variety of **engineering** and **scientific** tasks may be formulated as **large, non-linear, constraint optimization** problems, e.g.:

1. **Residual stress** analysis in railroad rails and vehicle wheels

   (**direct** theoretical problem).

2. **Physically based approximation of experimental data**, e.g.

   residual stress reconstruction using experimentally measured data e.g.

   strain gauge technique, Moire interferometry, or neutronography.

   (**inverse** hybrid theoretical – experimental problem).

Efficient solution of such type optimization problems is often crucial for various **practical engineering** applications.

Solution methods used (convex, and non-convex problems):

deterministic like

- **FDM** (Feasible Directions Method)
- Penalty Methods

and/or **stochastic** like

- **AI** (e.g. NN or **Evolutionary Algorithms**)

Introduction

Research objective

Significant **acceleration** of the **EA** applied to **large, non-linear constraint optimization** problems, where a **function** (given e.g. by its **nodal values**) is searched,
and **solving** of problems that **could not be solved** by the **standard** EA technique
(e.g. extremely large ones).

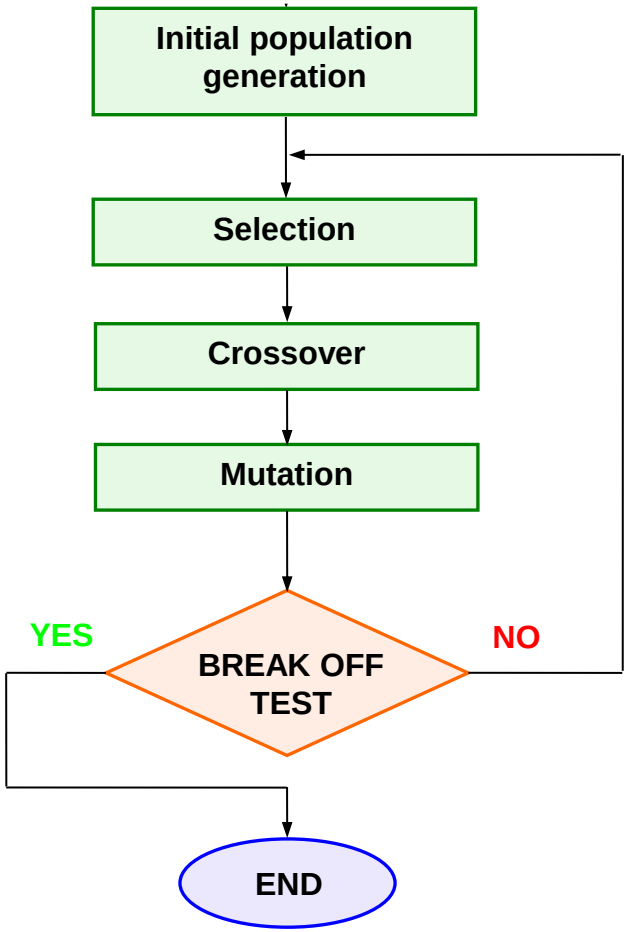
The **speed-up** is based on:

- choice of the **most efficient combination** of the evolutionary operators:
  selection, crossover, mutation,
- use of several **new** simple **speed-up techniques proposed** here,
- further **development** of chosen **existing** EA acceleration methods.

Standard Evolutionary Algorithm used

Choice of the **most efficient combination** of evolutionary operators

- **Selection** operators:
  - **rank**
  - tournament
- **Crossover** operators:
  - simple
  - arithmetic
  - **heuristic**
- **Mutation** operators:
  - uniform
  - **non-uniform**
  - boundary



Acceleration techniques considered

Newly proposed simple acceleration techniques:

- **smoothing** of the direct and **balancing** of smoothed EA solution,
- use of **a' posteriori error analysis** and non-standard **parallel** and **distributed** calculations,
- step by step **adaptive mesh refinement**.

Development of chosen **existing** techniques

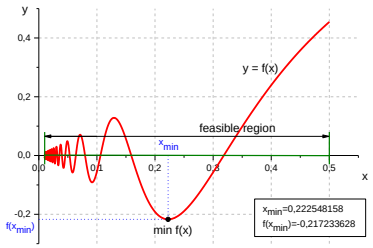
a) **Already investigated**:

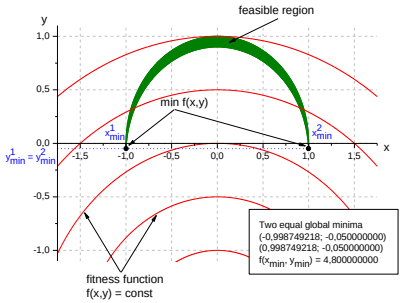
- effective **constraint handling** technique,
- techniques based on **estimation** of the **convergence point** of population,
- **population averaging**.

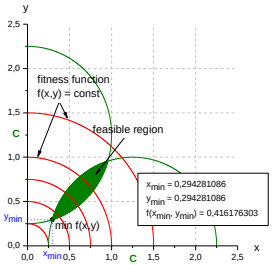
b) **Planned**:

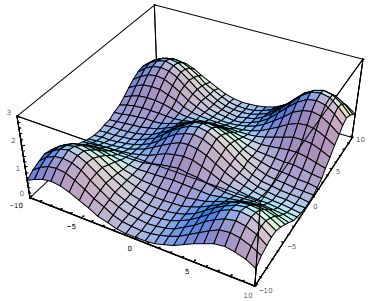
- **hybrid** algorithms (EA + deterministic method),
- **distributed** and **parallel** algorithms,
- **new** evolutionary **operators** (e. g. gradient mutation, cloning).

Benchmark Problems

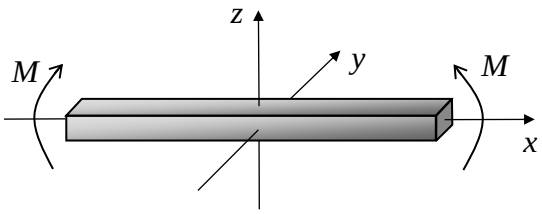


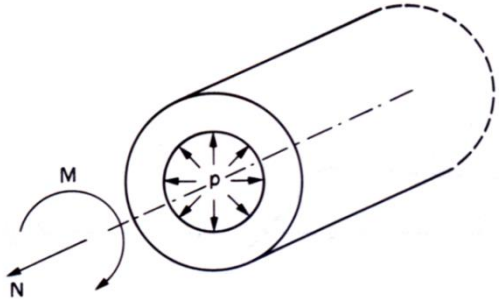


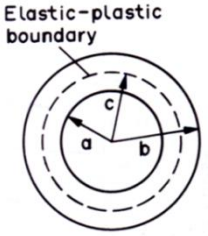


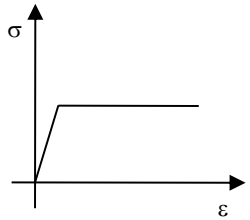


Residual stress analysis in cyclically bending bar and in the thick-walled cylinder under various cyclic loadings





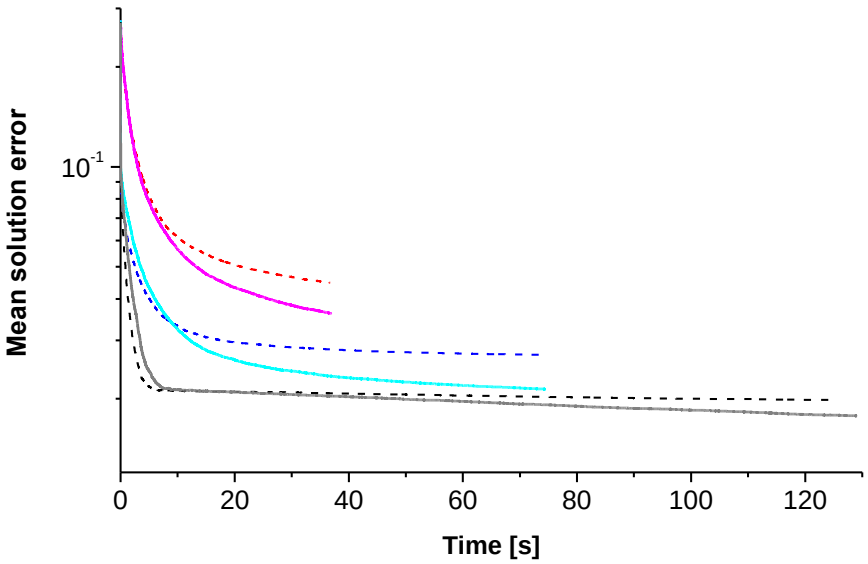




PBA benchmarks, e.g. smoothing of beam deflections and reconstruction of residual stresses based on pseudo-experimental data

Example: Residual stress analysis

In the thick-walled cylinder under cyclic internal pressure (1D model)

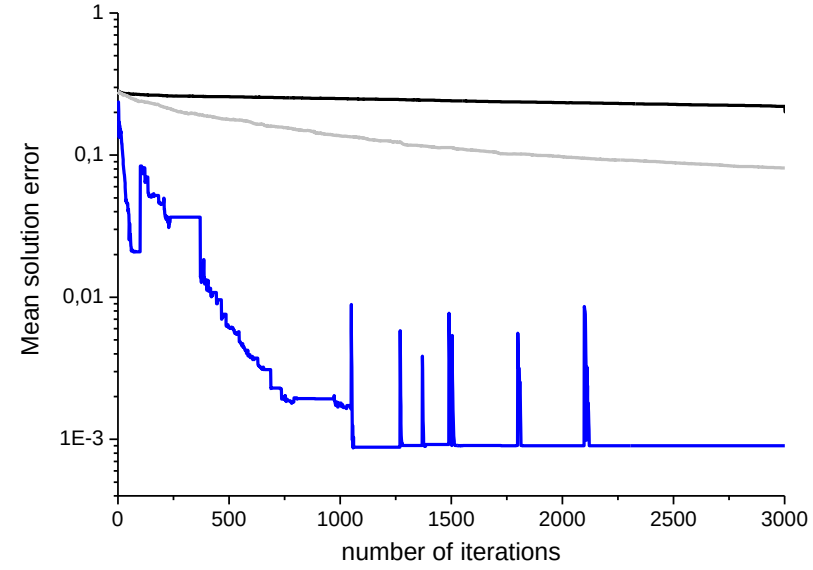


standard approach: $\beta = 1$ $\beta = 2$

population averaging: $\beta = 1$ $\beta = 2$

estimation of convergence point - approximated apprach:

$\beta = 1$ $\beta = 2$



Number of decision variables: up to about 3000

Total speed-up: up to about 140 times

THANK YOU VERY MUCH FOR ATTENTION